

RADIANT LIGHT AND HEAT<sup>1</sup>

## III. (Continued)

*Absorption—Terrestrial Applications.*

LET us next consider the absorption spectra of substances, that is to say, the absorption lines which substances at ordinary temperatures produce in the spectrum of light from a high temperature source, such as the sun or the electric arc. This absorption may either be general or selective; it may be spread over a large portion of the spectrum, or it may act specially over a very limited district or line. It is in the latter case that we derive most advantage by studying absorption spectra, and there are many substances which may be known at a glance by means of their peculiar absorption. Professor Stokes has shown, for instance, that blood may at once be distinguished from other solutions of similar tint by means of the characteristic dark bands which it produces. By means of a spectrum microscope Mr. Sorby thinks that the thousandth part of a grain of blood may be detected, and the same observer asserts that wines of different vintages can easily be distinguished from one another in the same way. It thus appears that the absorption spectrum may in many cases furnish us with an efficient and simple means of ascertaining adulteration, for the presence of inferior substances which escape detection by the taste or sight will at once be recognised when spectrum analysis is employed. Russell, Gladstone, Abney, Festing, and others have studied with much success the spectra of solid and liquid bodies.

The absorption spectra of gases and vapours at low temperatures have been studied by various physicists, and amongst them by Janssen, Roscoe, Schuster, and Lockyer. Brewster, as we have seen, was the first to observe the effect produced on the solar spectrum by nitrous acid gas; other gases have since been tried in the same way, and many of these give out channelled or fluted absorption lines similar to those given out by nitrous acid gas. In fine, various researches lead us to conclude that gases, and more especially vapours, are in a state of greater molecular complexity at a low than at a high temperature, for at a low temperature they have a prominent absorption for many kinds of rays, whereas at a high temperature they have no such strong absorptive power, but absorb and radiate only a few definite spectral lines.

This simplification produced in spectra by the rise of temperature has been greatly insisted on by Lockyer, and will again come under our review when we have discussed the celestial applications of spectrum analysis.

Meanwhile, I cannot do better than quote the words of Lockyer in his Treatise on the Spectroscope and its applications (NATURE Series):—"We may state generally (says that observer) that beginning with one element in its most rarified condition, and then following its spectrum as the molecules come nearer together, so as at last to reach the solid form, we shall find that spectrum become more complicated as this approach takes place, until at last a continuous spectrum is reached."

Before concluding this division of my subject, it will be necessary to allude to the absorptive effect produced by the earth's atmosphere on the light and heat of the sun. This is a point of great practical as well as scientific importance, more especially if we reflect that the atmosphere is a covering of variable composition, and that the variable element (aqueous vapour) is one which no doubt exercises a large absorptive influence upon the rays of the sun. But there is another element of variability in the sun itself, for we more than suspect that the amount of radiant energy which we receive from our luminary depends to some unknown extent upon the state of his surface, and may thus be different in years characterised by a maximum number of sun spots, and in years characterised by a small number of these phenomena. An

additional complication is introduced by the suspicion that one of these causes of variability may react upon the other in such a way that in those years when the radiation of the sun is intrinsically most powerful (if there be such) an abnormally large amount of aqueous vapour may be dissolved in the air, so that we may have on such occasions an increased absorption as well as a large intrinsic radiation, and the one of these causes may thus, to a great extent, cover or conceal the other.

Bearing these points in mind, I shall divide my remarks into two sections. I shall treat, *in the first place*, of the means which we have at our disposal for estimating the whole amount of radiant energy which reaches us from the sun at any station, whether this be near the level of the sea or at an elevation above it.

*In the second place*, I shall allude to the means we have at our disposal for estimating the amount of any one kind of radiant energy that reaches us from the sun.

An instrument by means of which we may ascertain the amount of the sun's radiant energy is called an *Actinometer*.

I have recently suggested such an instrument for measuring the heating effect of the sun, which has been tried at various stations, and appears to work well. It consists of a thick hollow cube of brass, surrounded with felt, and then again with a covering of polished brass. Into the interior of this chamber a suitable thermometer is inserted, its bulb being exactly in the centre. There is a small hole in one of the sides, through which the heat of the sun condensed by a lens is made to fall upon the bulb of the thermometer, the instrument having a motion in altitude and azimuth so as to enable it to catch the sun readily. The exposure is made for a definite time, as given by a good chronometer.

Instruments of this kind have been established in various places and at various elevations, and we shall certainly be able to derive from them information of importance as regards the meteorology of the place. To what extent we shall be able by their means to separate between the two apparent causes of solar variability, namely, that due to an intrinsic change in the sun itself, and that due to a change in the constitution of the earth's atmosphere, is perhaps an open question. It may be hoped that such an instrument may at least enable us to advance the problem, even if it prove insufficient to bring it to a complete solution.

Again, Professor Sir Henry Roscoe has invented an instrument intended to record the effect of the sun in blackening chloride of silver. He is able to prepare a paper of a standard sensitiveness, which, by an automatic arrangement, is exposed for known intervals of time. This is an instrument from which we shall no doubt obtain valuable information, more especially as the more refrangible rays of the sun play an important part in terrestrial economy. Still, however, it does not at first sight escape the objection above mentioned, or enable us to discriminate between the two apparent causes of solar variability—the celestial and the atmospheric.

It has been remarked by the Solar Physics Committee, in their report to the British Government (page 66) that by comparing with a standard certain definite regions of the solar spectrum, unabsorbed by any of the constituents of the earth's atmosphere, we might be able to ascertain any variation in the quantity or in the quality of the true solar radiation. This leads me to inquire what means we have at present of estimating the amount of any particular kind of ray which we receive from the sun. In the first place, we have the recent extension by Captain Abney of the powers of photography, in virtue of which it is not too much to assert that we can now obtain a complete map of the solar spectrum, with its absorption lines extending greatly beyond the visible spectrum on either side. We have also the invention and successful construc-

<sup>1</sup> Continued from p. 425.

tion by Professor Langley of his Bolometer, which is an instrument for detecting and measuring small quantities of radiant heat much more sensitive than the thermopile. It depends upon the fact that the electrical resistance of a metal is increased as it rises in temperature. Suppose, now, that two circuits conveying equal and opposite currents meet in a galvanometer, the needle will of course remain at rest. If, however, a portion of one of these two circuits be heated, its resistance will be increased, and the current passing through it will thus be diminished. The two opposing currents will now no longer balance each other, and in consequence the galvanometer needle will be deflected.

In the bolometer the two circuits each contain a sheet of extremely thin platinum foil, so that a very small

shaded curve above the spectrum represents the observations made by Professor Langley with his Bolometer at the foot of the mountain. We have next a dotted curve derived from observations at the top of the mountain, and, finally, another representing the probable curve of solar energy above the limits of the atmosphere. It follows from these curves that if we could view the sun beyond the limits of the atmosphere the light would be decidedly blue.

There can be no doubt that the improved process of photography devised by Captain Abney, and the Bolometer of Professor Langley, furnish us with excellent differential instruments by which we may compare at any place and moment the relative distribution of solar energy over the various parts of the spectrum.

If either of these observers could produce such a uniformity in his process that his results of to-day should be exactly comparable with those ten or twelve years afterwards, then his method would go far to obtain for us the requisite information regarding solar variability. But I fear that we cannot expect this, at any rate for some time to come. As it is, we learn by the foregoing diagram what are the regions of the solar spectrum most affected by the selective absorption of the components of the earth's atmosphere, for Professor Langley imagines that the gaps in the shaded curve are caused by this means.

Let me now venture, in conclusion, to make the following suggestion. By aid of the information furnished by the instruments now described, let us select certain regions of the spectrum for which in the shaded curve there are no gaps, and in the spectrum below it no corresponding dark lines; that is to say, regions for which there is no selective absorption. Now let us throw the energy from these selected regions either upon the standard sensitive paper of Roscoe's actinometer, or upon the thermometer of a suitable heat-actinometer, or upon both.

We shall by this means greatly simplify the problem under consideration, since these instruments will now be recording the intensity from year to year of those portions of the solar spectrum which are not subject, as far as we know, to selective absorption from the variable constituent of the atmosphere of the earth.

It is possible that the rays which blacken chloride of silver are rays on which this variable constituent exercises little or no selective absorption, although the general absorption of these rays is no doubt very considerable:

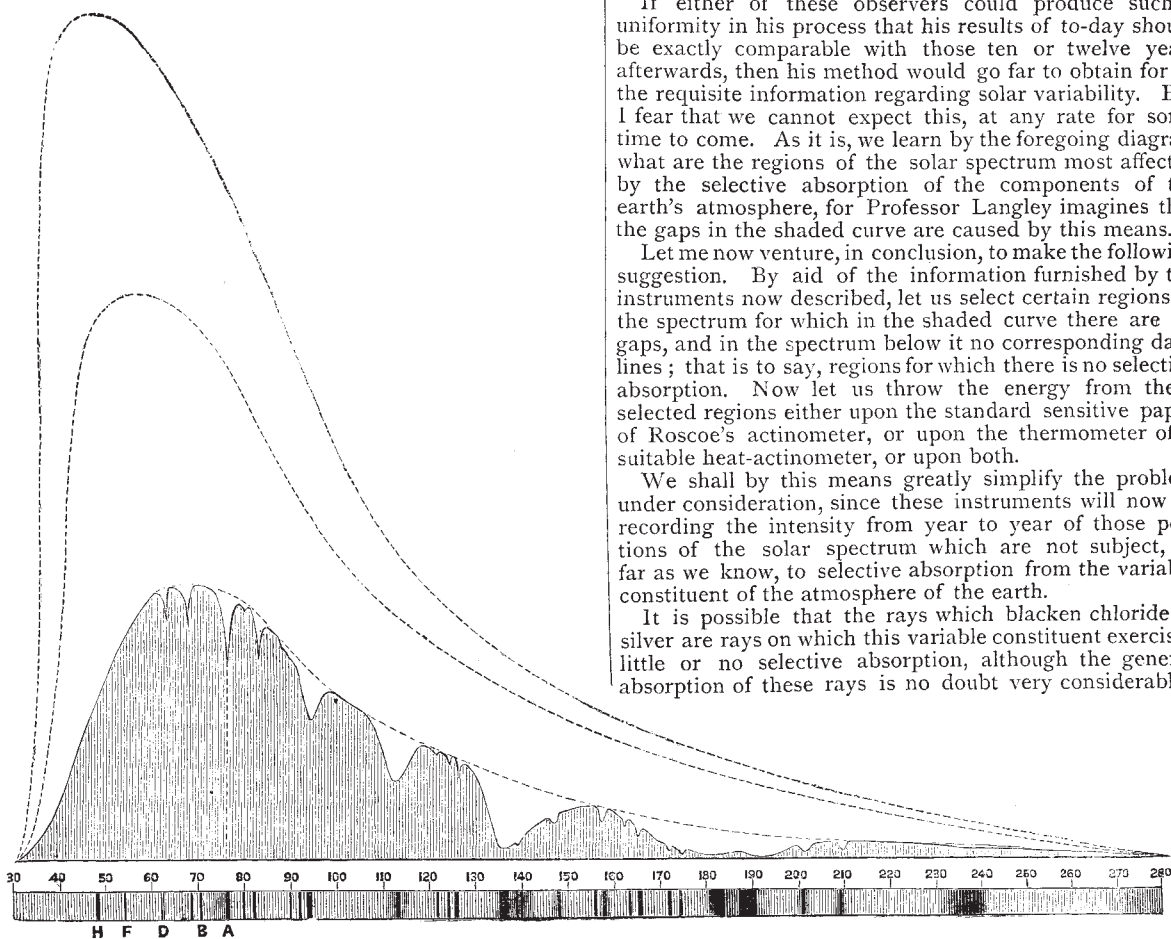


FIG. 10.

quantity of radiant heat falling upon these may produce a considerable result. These sheets may be compared to the two faces of the pile, and if the one be heated we shall have a current in the one direction, while if the other be heated we shall have a current in the opposite direction. By this instrument Professor Langley has determined with much precision the exact distribution of energy in the solar spectrum. But he has done more than this: he has carried his instrument up to the top of Mount Whitney, in America, and has thus procured us much information regarding the absorbent effect of the various constituents of the earth's atmosphere.

The following diagram (Fig. 10) exhibits the result of his researches. In it the lower band represents the solar spectrum as obtained by a perfect method. The

in this case no special adaptation to the chemical actinometer would be necessary.

To conclude, I think we may entertain a well-grounded hope that by patience and persistence in these or similar means, we shall ultimately arrive at a definite solution of this very interesting and important problem.

BALFOUR STEWART

(To be continued.)

#### NOTES

THE Geological Congress met last week at Berlin. England was represented by Messrs. Geikie, Hughes, Bauermann, Hinde, Marr, Topley, White, Woodall, Lieut.-Col. Tabuteau, and